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Original Article

Low frequency tapping systems applied to young-tapped trees of *Hevea brasiliensis* (Willd. ex A. Juss.) Müll. Arg. in Southern Thailand

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ABSTRACT

A declining rubber price and labor shortages in the context of climate variability are problems for rubber smallholders. A low frequency tapping system that may be a solution to these problems was tested in southern Thailand using eight-year-old trees of the RRIM600 clone at the Thepa Research Station, Songkhla province. The experimental design was a randomized complete block with five treatments defined in Table 1 and abbreviated to: T1: S/3 d1 2d/3; T2: S/2 d2; T3: S/2 d3 ET 2.5% Pa1 (1) 8/y (m); T4: S/3 d2 ET 2.5% Pa1 (1) 4/y (m); and T5: S/3 d3 ET 2.5% Pa1 (1) 12/y (m). There were three replications (elementary plot) with 10 trees per treatment in each elementary plot. The results showed that low frequency tapping systems (d3) with stimulation resulted in an equivalent yield in cumulative latex production compared with the other tapping systems and also had higher latex production per tapping. Bark consumption was less in the low frequency tapping systems leading to the possibility of lengthening the economic lifespan of the tapping panels of the tree. A low frequency tapping treatment with stimulation eight times per year induced decreases in the total solids, sucrose and reduced thiol contents; however, the inorganic phosphorus content increased, as is usually seen with the use of ethylene stimulation. The response of rubber trees to a low frequency tapping system should now be tested in the long term.

Introduction

The rubber tree (*Hevea brasiliensis* (Willd. ex A. Juss.) Müll. Arg.) is grown globally as a tropical tree crop for the industrial production of latex (Purseglove, 1987). In Thailand, different tapping systems are used in each region (Chambon et al., 2014). Therefore, choosing an appropriate tapping system is an essential factor to determine the yield and physiology of rubber trees. Currently, high frequency tapping systems are commonly used (Chantuma et al., 2011) because they can compensate for the reduction of tapping days that leads to loss of revenue due to weather variability and rubber price fluctuations. However, such a system may have an adverse effect on the physiology of the rubber trees and the duration of tapping of the trees. Therefore, low frequency tapping systems (Soumahin et al., 2009, 2010; Kudaligama et al., 2010; Prasanna et al., 2010) have been applied to reduce the risks to rubber production, namely a short producing period and lack of manpower. Moreover, several researchers have been trying to improve these systems by using chemical stimulation. Thus, 2-chloroethylphosphonic acid (ethephon) has been applied with low frequency tapping systems and Gohet et al. (1995) reported that the chemical stimulation effect may vary with rubber tree clones. Ethephon releases ethylene gas to enhance latex yield because it increases the duration of latex flow after tapping with the reduction of latex coagulation by activating latex cell metabolism (Jacob et al., 1989; d'Auzac et al., 1997). This leads to enhanced land and labor productivity. Consequently, both small-scale planters and agro-industrial plantations worldwide use an ethylene generator applied to the tapping panel (Sivakumaran and Chong, 1994; Jetro and Simon, 2007; Lacote et al., 2010; Njukeng et al., 2011; Traore et al., 2011; Sainoi and Sdoodee, 2012). In southern Thailand, low frequency tapping systems with stimulation are not commonly used. Hence, the objective of this study was to test the efficiency of low frequency tapping systems with

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stimulation as a guideline for rubber smallholders in southern Thailand. Furthermore, the effects were also investigated of low frequency tapping systems with stimulation on young-tapped rubber trees with regard to the yield, physiology and latex biochemistry.

Materials and methods

Experimental site

The experiment was carried out at the Thepa Research Station (6°48′0.7″N, 100°56′37.2″E, altitude 33 m above mean sea level) in Thepa district, Songkhla province in southern Thailand. The climate is subtropical with two distinct seasons (dry and rainy season) (Sternstein, 1962; Thai Meteorological Department, 2013). The dry season is from mid-February to mid-May, and the rainy season is from mid-May to mid-February. This region is characterized by a temperature range of 22–33 °C, the mean relative humidity is 79% and annual rainfall is 2000 mm or more (Thai Meteorological Department, 2013). The soil type in the trial area is sandy loam, Coated, isohyperthermic, Typic Quartzipsamments with pH 5.5 (Sainoi and Sdoodee, 2012).

Plant material

Clone RRIM 600 was used in the experiment. This clone was planted (7 m × 3 m spacing) in 2005 and the experiment was started in August 2013 with 8-year-old trees. The trees were selected before tapping based on homogenous girth of the trunk and open at 1.50 m from the ground on panel BO-1.

Experimental treatments and design

The experiment was arranged as a randomized complete block design with five treatments comprising three replications (elementary plot) and 10 trees per treatment in each elementary plot. The tapping notations were arranged according to Vijayakumar et al. (2009) and are shown in Table 1.

Data collection and analysis

The latex yield was assessed based on coagulated rubber or cup lumps, which were weighed from each tree every month before air-drying until reaching a constant weight, which was then determined as dry rubber. The latex yield was calculated by subtracting 15% of the moisture content from the total dry rubber weight and expressing it as kilograms/tree and grams/tree/tapping. The girth increment (in centimeters) was measured every year in March at 1.70 m above the ground level. Bark consumption (in centimeters) was measured on the tapped panel every year from the beginning to the end of the tapping period. Latex biochemistry or latex diagnosis was assessed every month and reported as average values from the beginning to the end of the month in which the data were collected. Sampling was applied on the trunk at the middle of the cut, approximately 5 cm below the under tapping cut (downward tapping) of rubber trees. Pooled latex sampling was applied (Jacob et al., 1989). The latex biochemical parameters measured were the total solid content as a percentage and the sucrose content, inorganic phosphorus content and reduced thiol content as microMoles and were analyzed according to the method developed by CIRAD and CNRA and adapted in 1995 by IRRDB (Jacob et al., 1988; referred to by Lacote et al., 2004). Statistical analysis of all data was done using the DSAASTAT version 1.1 software package (Onofri, 2007).

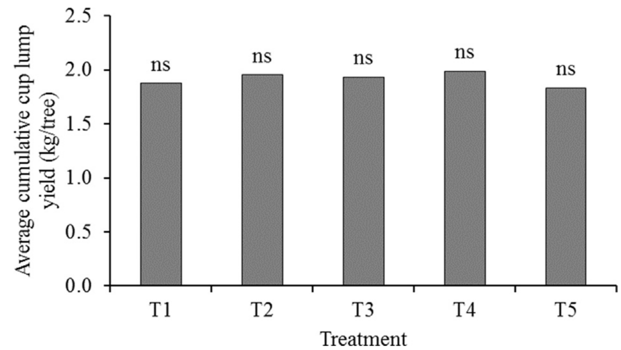

Fig. 1. Average cumulative cup lump yield of the five treatments during August 2013–February 2014: T1: S/3 d1 2d/3; T2: S/2 d2; T3: S/2 d3 ET 2.5% Pa1 (1) 8/y (m); T4: S/3 d2 ET 2.5% Pa1 (1) 4/y (m); T5: S/3 d3 ET 2.5% Pa1 (1) 12/y (m)—see Table 1 for definitions; ns = no significant difference.

Results

Latex production

There were no significant differences in the average cumulative cup lump yield data among treatments (Fig. 1). However, the average cumulative cup lump yield of T4 produced the highest yield (1.99 kg/tree) while T5 had the lowest yield (1.83 kg/tree). Comparing the average cumulative cup lump yield for the different tapping cut lengths with the same tapping frequency, it was found that the yield of T4 for the d2 frequency was higher than that of T2 with a longer cut length, because it was compensated for by ethylene stimulation. Moreover, for the d3 tapping frequency, the yield of T3 was higher than that of T5 with a shorter cut length.

The average cup lump yield of the five treatments was significantly different (Fig. 2); T3 had the highest yield (69.0 g/tree/tapping) and T1 had the lowest yield (40.8 g/tree/tapping). Compared to T1, the percentage increase in yield for T2, T3, T4 and T5 was 37%,

Table 1
Treatments (tapping systems) used in the experiment.

Treatment	Tapping system	Description	TI[a]
T1	S/3 d1 2d/3	Third spiral cut downward at daily tapping, two days in tapping followed by one day of tapping rest in three days	89
T2	S/2 d2	Half spiral cut downward at alternate daily tapping	100
T3	S/2 d3 ET 2.5% Pa1 (1) 8/y (m)	Half spiral cut downward at third daily tapping, stimulated with ethephon of 2.5% active ingredient with 1 g of stimulant applied on panel on 1 cm band, 8 applications per year	67
T4	S/3 d2 ET 2.5% Pa1 (1) 4/y (m)	Third spiral cut downward at alternate daily tapping, stimulated with ethephon of 2.5% active ingredient with 1 g of stimulant applied on panel on 1 cm band, 4 applications per year	67
T5	S/3 d3 ET 2.5% Pa1 (1) 12/y (m)	Third spiral cut downward at third daily tapping, stimulated with ethephon of 2.5% active ingredient with 1 g of stimulant applied on panel on 1 cm band, 12 applications per year	44

Tapping notations arranged according to Vijayakumar et al. (2009).
[a] Mean tapping intensity.

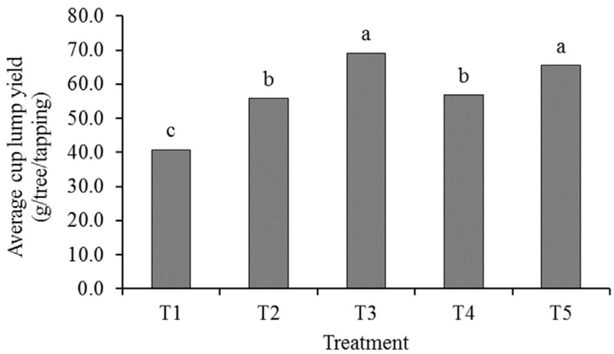

Fig. 2. Average cup lump yield of the five treatments during August 2013–February 2014: T1: S/3 d1 2d/3; T2: S/2 d2; T3: S/2 d3 ET 2.5% Pa1 (1) 8/y (m); T4: S/3 d2 ET 2.5% Pa1 (1) 4/y (m); T5: S/3 d3 ET 2.5% Pa1 (1) 12/y (m)—see Table 1 for definitions; different letters above each bar indicate significant difference at $p \leq 0.05$ by Duncan's multiple range test.

69%, 39% and 61%, respectively. There was no significant difference in the average yield per tree per trapping among the treatments for different tapping cut lengths and the same tapping frequency. However, the reduction of tapping frequency treatments resulted in a higher average yield per tree per tapping than the conventional treatment in S/2d2.

Latex biochemistry

There were no significant differences in the average total solid content (TSC) among the treatments. The TSC varied in the range 52.65–55.27% and was highest in T1. It was found that the half spiral tapping cut length treatments caused a greater reduction in the TSC than the third spiral tapping cut length treatments. The sucrose content (Suc), inorganic phosphorus content (Pi) and reduced thiol content (RSH) were significantly different among the treatments (Table 2). Suc was greatest in T1. Suc for the reduced tapping frequency (d3) treatments was lower than in the higher tapping frequency (2d/3, d2) treatments. Pi was greatest in T3. Pi in the reduced tapping frequency (d3) treatments was higher than in the higher tapping frequency (2d/3, d2) treatments. RSH was highest in T1. A half spiral cut length with a reduction in the tapping frequency (S/2 d3) with ethylene stimulation decreased RSH.

Girth increment

There were significant differences among the five treatments (Fig. 3). The average girth increment in T1 (1.65 cm) was the highest and was lowest in T2 (1.25 cm). Low frequency tapping systems

Table 2
Latex biochemistry (TSC = total solid content, Suc = sucrose content, Pi = inorganic phosphorus content and RSH = reduced thiol content) of five treatments in first tapping year (August 2013–May 2014).

Treatment†	TSC (%)	Suc (mM)	Pi (mM)	RSH (mM)
T1: S/3 d1 2d/3	55.27	$10.97^{a\ddagger}$	17.17^{b}	0.24^{a}
T2: S/2 d2	53.26	9.67^{ab}	17.31^{b}	0.22^{a}
T3: S/2 d3 ET 2.5% Pa1 (1) 8/y (m)	52.65	7.74^{b}	20.97^{a}	0.17^{b}
T4: S/3 d2 ET 2.5% Pa1 (1) 4/y (m)	54.29	9.56^{ab}	17.52^{b}	0.22^{a}
T5: S/3 d3 ET 2.5% Pa1 (1) 12/y (m)	54.09	7.79^{b}	18.61^{ab}	0.22^{a}
F-test	ns	*	*	*
Coefficient of variation (%)	3.85	12.90	7.18	8.95

* = significant difference ($p \leq 0.05$).
† Treatments are defined in Table 1.
‡ Values with different lowercase letters in the same column are significantly different by Duncan's multiple range test; ns = no significant difference.

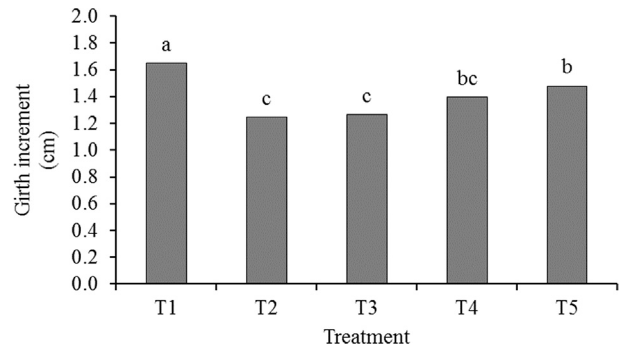

Fig. 3. Girth increments (cm) of the five treatments during August 2013–February 2014: T1: S/3 d1 2d/3, T2: S/2 d2, T3: S/2 d3 ET 2.5% Pa1 (1) 8/y (m), T4: S/3 d2 ET 2.5% Pa1 (1) 4/y (m), T5: S/3 d3 ET 2.5% Pa1 (1) 12/y (m) —see Table 1 for definitions; different letters above bars indicate significant difference at $p \leq 0.05$ by Duncan's multiple range test.

showed higher girth increment than the d2 tapping frequency. The tapping cut length clearly affected the girth increment. The half spiral cut treatments exhibited lower girth increment than in the third spiral cut treatments. Moreover, the third spiral cut length treatments with stimulation showed lower girth increment than the non-stimulation treatment.

Bark consumption

The average bark consumption was significantly different among the five treatments (Fig. 4), with T1 having the highest (11.7 cm) whereas T3 had the lowest bark consumption (8.3 cm).

Discussion

The cumulative yields from the low frequency tapping systems were not significantly different from the conventional treatment, S/2 d2 and S/3 d2 with ethylene stimulation. However, low frequency tapping systems (d3) markedly had the highest yield per tree and per tapping. This indicated that the reduction in the tapping frequency with stimulation can compensate for the cumulative yield per tree with higher yield per tapping. Rodrigo et al. (2011) concluded that increasing the yield per tree per tapping with low frequency tapping systems with the use of ethylene stimulation could compensate for the amount of cumulative yield per year. These results were also supported by Jetro and Simon (2007), who mentioned that a low frequency tapping system must be applied

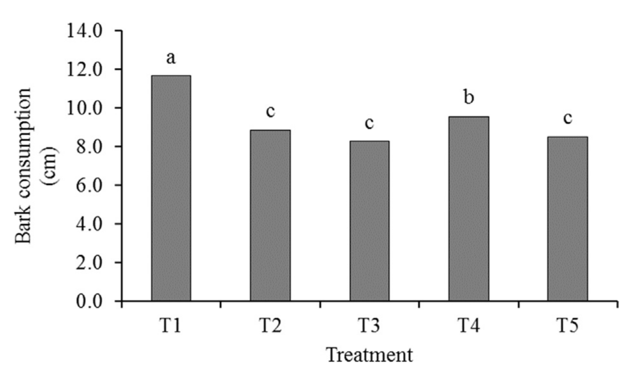

Fig. 4. Bark consumption of the five treatments during August 2013–February 2014: T1: S/3 d1 2d/3; T2: S/2 d2; T3: S/2 d3 ET 2.5% Pa1 (1) 8/y (m); T4: S/3 d2 ET 2.5% Pa1 (1) 4/y (m); T5: S/3 d3 ET 2.5% Pa1 (1) 12/y (m) —see Table 1 for definitions; different letters above each bar indicate significant difference at $p \leq 0.05$ by Duncan's multiple range test.

with stimulation to increased the potential of this system when using fewer tapping days and Senevirathna et al. (2007) noted that this tapping system was more suitable to minimize the incidence of tapping panel dryness (TPD). This has been tested with a low frequency tapping system under the drier climatic conditions in Sri Lanka where there was no indication of increased incidence of TPD (Kudaligama et al., 2010). In the current experiment, under alternate daily tapping (d2), third spiral cut length (S/3) with ethylene stimulation provided a cumulative yield and yield per tapping that was higher than for the half spiral cut length (S/2) without stimulation. The third daily tapping (d3) in the low frequency tapping systems, half spiral cut length (S/2) with stimulation provided higher cumulative yield and yield per tapping than the third spiral cut length (S/3) with ethylene stimulation. The number of two consecutive tapping days was inversely proportional to the yield per tapping, which indicated that low frequency tapping could allow for good regeneration of the extracted cellular contents (Obouayeba et al., 2009b).

In the current study, the latex biochemistry considered the total solid content (TSC), sucrose content (Suc), inorganic phosphorus content (Pi) and reduced thiol content (RSH). There was no effect of length of tapping cut and tapping frequency on the TSC. A decrease in Suc was clear in the low frequency tapping systems (d3) with ethylene stimulation. However, the yield per tree per tapping was the highest for the d3 treatments due to the high volume of latex removed at each tapping. Hence, low Suc indicated that compensation in the latex regeneration process after each tapping was intensive under ethylene stimulation (Jacob et al., 1989; Lacote et al., 2004) leading to a depletion of sucrose in the latex (Gohet et al., 2003; Obouayeba et al., 2009b; Rodrigo et al., 2011). The current results showed that the sugar loading capacity of the latex cells, considered as the ability of the sink to import carbohydrates (Tupy and Primot, 1976; Ho, 1988; Patrick, 1997; Silpi et al., 2007), was one of the main factors that enables a significant increase in latex yield after ethylene stimulation (Gohet et al., 2001; 2003) and after each tapping in a low tapping system. Pi was the highest for the low frequency tapping system (d3) with ethylene stimulation, mainly with the longest cut (S/2). High Pi reflects good metabolic activity of latex production (Jacob et al., 1988; 1989; Gohet et al., 2003; Lacote et al., 2010). This was the case with the S/2 d3 treatment with ethylene stimulation leading to one of the highest yields. This implied that increasing the latex yield by increasing the metabolic activity with ethylene stimulation leading to high Pi, will deplete the Suc involved in the latex regeneration after each tapping to maintain a high yield. In a low frequency tapping system, ethylene stimulation increased rubber biosynthesis and latex yield more efficiently at each tapping making it possible to compensate for the lower number of tappings. RSH decreased in the low frequency tapping systems for the half spiral treatment. A long cut length with stimulation induced RSH. Obouayeba et al. (2011) showed that colloidal stability of the latex was more preserved with short cut lengths than long cuts length. A longer cut (S/2) combined with a lower tapping frequency (d3) led to an increased yield at each tapping and the latex cell metabolism was enhanced by the use of ethylene stimulation.

Girth increment was sensitive to cut length in each treatment. A shorter cut length resulted in a better girth increment than a longer cut length. This was in accordance with Obouayeba et al. (2011) who concluded that the reduction of tapping cut length enhanced vegetative radial growth. Low frequency tapping systems resulted in higher girth increment than tapping system with a longer cut length (S/2). This was confirmed by Nugawela et al. (2000); a low frequency tapping system with stimulation did not have any negative effect on the growth of rubber trees with latex extraction in more than alternate daily tapping (d2) systems. In the current experiment, the girth increment was reduced for the lower tapping frequency (d3) and for a longer cut (S/2) with ethylene stimulation when the yield per tree and per tapping were the highest. It seemed that taking more latex at each tapping, when reducing the tapping frequency, could induce a lower growth rate in the trees. This was in accordance with Obouayeba et al. (2009a) who suggested that the growth of rubber trees decreased when the rubber yield increased. Therefore, combining the length of the tapping cut (S/2) with a low tapping frequency (d3) and the use of ethylene stimulation leading to a significantly increased yield at each tapping, reduced the girth increment of the trees.

Bark consumption in low frequency tapping systems was markedly decreased compared to the conventional tapping system in Thailand (S/2 d2). Less bark consumption was due to fewer tapping days, leading to an increased economic life span of the rubber trees (Nugawela et al., 2000). Rodrigo (2007) considered this a benefit for rubber smallholder because it may increase the replanting cycle up from 30 years to 36 years. Furthermore, the commencement of tapping in renewed bark could be delayed, which may increase the time for latex regeneration (Rodrigo et al., 2011).

With young-tapping of rubber trees of the RRIM600 clone in southern Thailand, the yield of low frequency tapping systems with ethylene stimulation was equivalent to the conventional latex harvesting system with d2 frequency. There was higher latex production per tapping due to the activation of the latex cell metabolism by ethylene stimulation. There was an adverse effect on girth increment when the yield at each tapping was high. Conversely, a decrease in bark consumption led to an increased economic life span of the trees. These results provide a guideline for rubber smallholders to optimize latex production by choosing the most appropriate latex harvesting system, including perhaps low frequency tapping with ethylene stimulation, to improve land and labor productivity.

Conflicts of interest

The authors declare that there are no conflicts of interest.

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